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Wavelength Tunability Assessment of a 170 Gbit/s transmitter using a Quantum Dash Fabry Perot mode-locked laser

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Abstract We demonstrate the tunability of a 170 Gbit/s transmitter based on a quantum dash mode-locked Fabry-Perot laser. Same performances are obtained over a 8 nm wavelength range simply by adjusting the shaping filter frequency.

Introduction

Semiconductor mode-locked laser diodes have shown an interesting potential for many applications such as all-optical clock recovery^{1,2,3}, high repetition rate source⁴ or for access network applications^{5,6}. Quantum dot based active layers bring to this technology remarkable optoelectronic properties owing to the 3 dimensional carrier confinement leading mainly to a broad gain bandwidth and to low phase noise level. For instance, 346 GHz pulse generation was demonstrated recently with QD MLLD by passive mode locking⁷. In this paper, we investigate the potential of this technology for the realisation of a wavelength tunable transmitter⁸ for bit rates up to 170 Gbit/s.

Laser characteristics

The device was fabricated at III-V lab. The Quantum dash Fabry-Perot mode locked laser (QD-FP-MLLD) was already described elsewhere^{3,4}. Along with the chip, a temperature probe and a Peltier cooler have been integrated into a butterfly module. In these experiments, the laser was actively mode-locked with an optical clock. A standard RZ 33% 42.7 GHz optical clock signal was generated at 1535 nm with a LiNbO₃ modulator and injected into the QD-FP-MLLD module through an optical circulator.

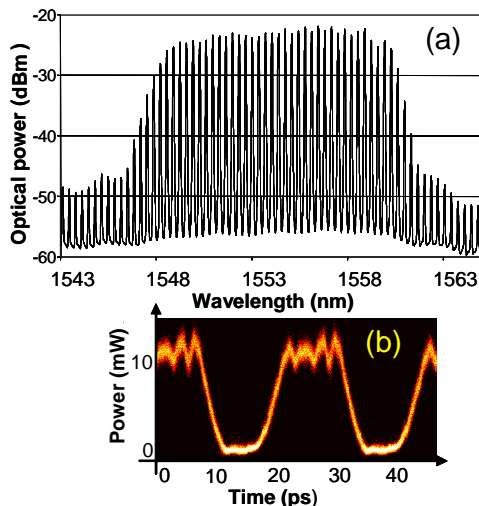


Fig. 1: Optical spectrum and corresponding eye diagram.

The optical spectrum with active mode-locking is shown in Fig. 1 (a), the spectrum is quite flat and centered at 1555 nm, with a 10 dB width of 13 nm. Due to the material dispersion of the component, this does not lead to transform limited pulses, but to the superposition of many pulses delayed in time as shown on Fig. 1 (b). One great potential of this source is the possibility of pulse shaping through optical filtering. The use of an arrayed waveguide filter would also offer the possibility to produce multiple pulsed signals with a single source.

170 Gbit/s experimental setup

The transmitter experimental set-up is shown in Fig. 2. The 42.7 GHz optical clock signal generated by the locked FP-MLLD is shaped thanks to a 3.5 nm supergaussian optical filter (2nd order). In this experiment, the transmitter wavelength was tuned from 1550 to 1558 nm by varying the filter central

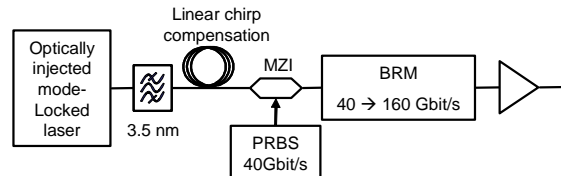


Fig. 2: Transmitter setup

frequency. Owing to the material dispersion of the laser, the resulting signal is slightly chirped; main part of this residual chirp is compensated for by a standard single mode fiber section. The same compensation was used for all the wavelengths in order to be more realistic from a WDM point of view. The optical clock was then modulated through a MZI modulator with a 42.7 Gbit/s 2⁷-1 pseudo random binary sequence (PRBS). A bit rate multiplier (BRM) finally multiplexes four delayed versions of the signal and provides a 170 Gbit/s data stream. The 170 Gbit/s pulses full widths at half maximum are comprised between 1.5 and 2 ps on the considered spectral bandwidth. Fig. 3 shows the eye diagrams of the generated 170 Gbit/s signal at 1550, 1553, 1555 and 1558 nm observed on an optical sampling oscilloscope (OSO).

These eye diagrams are slightly different due to a slight residual chirp; however they all show an actually low jitter (under the OSO resolution of 150 fs)

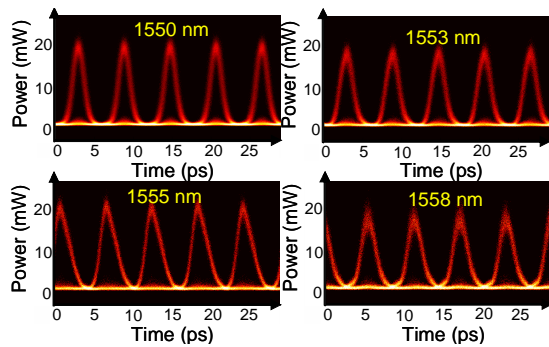


Fig. 3: 170 Gbit/s eye diagrams at 4 wavelengths.

and pulse characteristics compatible with a bit rate of 170 Gbit/s.

The receiver setup is shown on figure 4, the 170 Gbit/s data stream is optically demultiplexed down to 42.7 Gbit/s in an electro-optical loop which also recovers the 42.7 GHz clock. This loop is composed of an electro-optic absorption modulator (EAM), an optical delay line (ODL), a 42.7 Gbit/s electrical clock recovery and a high finesse electrical

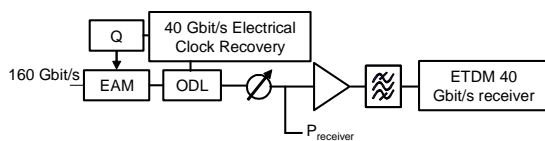


Fig. 4: Receiver setup.

band-pass filter (Q)⁹. This setup does not enable the analysis of the four 42.7 Gbit/s tributaries. Later on, the study is performed on one tributary only. The signal is then optically preamplified and received in a standard 42.7 Gbit/s electrical time division demultiplexing (ETDM) receiver for a bit error rate (BER) assessment at 10.67 Gbit/s.

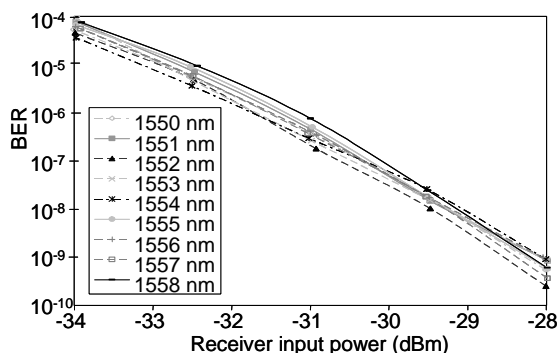


Fig. 5: BER measurements on a 9 nm bandwidth.

Measurements

The BER versus receiver input power was measured at 9 wavelengths between 1550 and 1558 nm by

varying the shaping filter central frequency after optical demultiplexing. Results are plotted on Figure 5. Roughly the same transmission quality is obtained for all the wavelengths and no error floor is observed. The receiver sensitivity at BER = 10⁻⁹ is plotted on Fig. 6 depicting values between -27.9 and -28.5 dBm on the 9 channels. This slight dispersion of the

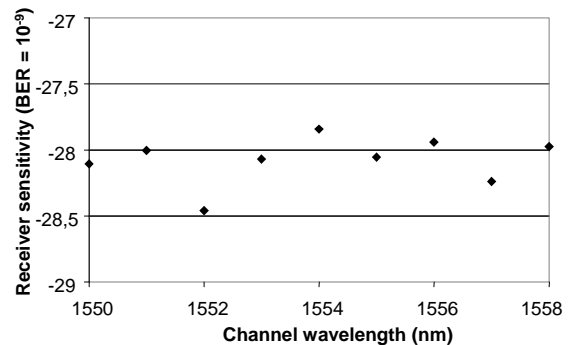


Fig. 6: Receiver sensitivity measurements at BER = 10⁻⁹.

sensitivity can be explained by the slight residual chirp affecting some wavelengths. This experiment shows the WDM compatibility at 170 Gbit/s of the QD-FP-MLLD module used as pulsed source.

Conclusions

We have presented the first 170 Gbit/s demonstration using a Quantum Dash Fabry Perot mode locked laser emitting optical pulses at 42.7 GHz. Pulses are shaped by an optical filter leading to short 1.5 ps wide pulses at 1550 nm after linear chirp compensation. This pulsed source is tunable simply by varying the shaping filter frequency, giving a great potential of this source for WDM applications notably. A sensitivity comprised between -27.9 and -28.5 dBm was obtained at BER = 10⁻⁹ with no error floor between 1550 and 1558 nm. A quite opened eye diagram showing a timing jitter compatible with 170 Gbit/s applications was obtained.

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